computation:

the micro
and
the macro view

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edited by

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COMPUTATION: THE MICRO AND THE MACRO VIEW

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PREFACE

It is no exaggeration to state that the computer has become part and parcel of the intellectual framework of our time. From routine information processing to metaphor for the workings of the mind, computation nowadays pervades language, practice and thought.

It is therefore natural that along with the ubiquity of computers, the very nature of information processing is also becoming a legitimate domain of scientific research. In particular, since computation implies a physical substrate (be it paper, electronic states acting as bits of information, or memory elements for storage) a relevant question is the extent to which the laws and methods of physics can shed some light into the field.

This book provides a number of examples of the use of physics in order to gain insights into the fundamental limits and workings of information processing, be it localized in a single machine or distributed in large networks. These insights can be broadly classified into two approaches to computation: a microscopic and a macroscopic one.

By microscopic view it is meant an approach to computation that focuses on the fundamental limitations posed by the laws of physics, which range from unavoidable quantum fluctuations to the constraints imposed by the second law of thermodynamics. Here one ponders questions that range from the minimal amount of dissipation possible in a given computational step, to the possible construction of a reversible computer. Articles dealing with quantum limits on information transmission, and the relationship between algorithmic randomness and the second law of thermodynamics, give a broad view of the subject, along with concrete results that provide tight bounds on what is possible and what is not.

The other view has as focus the macroscopic behavior of computation, and examines both emergent phenomena and the dynamical aspects of large scale computation. Here the emphasis is on software issues, which are becoming dominant as larger systems are constructed. Problems such as those encountered in many artificial intelligence applications, or in virus propagation among machines of a network, to give a few examples, require finding universals whose specification would suffice

to predict overall behavior. Articles dealing with the power of cooperative problem solving, and on the epidemiology of computer viruses, illustrate the usefulness of statistical methods for understanding and quantifying those problems. Finally, the article on the use of physics concepts in computation shows how the notations of dimension, topology, temperature, and phase transitions, can be put to good use in the analysis of parallel computing.

I do hope that these chapters, along with the long list of references that they contain, will be useful to a public intrigued by the wide array of phenomena that arise in computation.

Palo Alto, California

Bernardo A. Huberman

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